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COMPARING RESIDUAL PRODUCTION FROM TWO ALCOHOL FUEL PROCESSES: AN ECONOMIC EVALUATION

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ABSTRACT

Alcohol may be produced from corn using one of several alternative processes. In this economic analysis, two processes, each with a somewhat different mix of by-product residues are compared. They are the conventional distillery process and a milling process. The milling process has higher capital and start-up costs, but these are more than offset by lower operating costs and higher by-product values. From a broader societal view the milling process is also favored since its by-products--corn gluten meal, corn gluten feed, fodder yeast, and corn oil--are better feed and food substitutes for soybean products than the distillers' dried grain and solubles produced from the conventional distillery process. This allows greater land substitution between soybeans and corn which results in somewhat lower food price increases at given levels of alcohol production.

INTRODUCTION

The economic production of fuel alcohol from crops involves a number of interrelated considerations ranging from land use changes to by-product substitution in feed and food markets. With grain crops as the alcohol feedstock, by-product production and utilization are important components in determining the economic viability of a fuel alcohol industry. Further, a massive quantity of energy feedstocks is needed to reach even a modest alcohol substitution level for conventional liquid fuels. Thus, there are macro or industry wide implications as well as micro or individual firm considerations. Very little research has been conducted to date on the full range of implications that must be considered as we attempt to properly structure a fuel alcohol from biomass industry.

This paper reports on an economic comparison of two alcohol production processes, the conventional distillery process where one residual distillerys' dried grain and solubles (DDGS) is produced, and a dry milling process where several by-products including corn oil, corn gluten meal, and corn gluten feed are produced. This analysis is carried out within a larger framework that takes account of available land, domestic and export feed and food needs and a full range of crop, feed, and food substitution to accommodate the use of the various by-products. This allows a careful assessment of both firm and industry wide implications of alcohol production. First, a brief technical description of the two processes is given. This is followed by a cost and return budget (firm level) comparison of the two processes. The major part of the paper assess the broad industry wide implications that would result from the choice of either process.

TECHNICAL BACKGROUND

Conventional Distillery Process

With the conventional distillery processing method, the corn is ground before it enters the alcohol fuel plant. Enzymes are then added to convert the corn's starch into sugar. Yeast is then used to convert the sugar into alcohol. The remaining components of the grain--vitamins, protein, minerals, fats, and fiber--are not affected by the alcohol production process. This remaining grain fraction when dried, is known as distillers' dried grain and solubles (DDGS). DDGS is a high protein, high fiber feed with about 27 percent crude protein and nine percent fiber.[6] Because of its high protein content, DDGS is used as a substitute for soybean meal. However, its high fiber content and poor amino acid balance limit the quantity that can be fed to swine and poultry. The approximate limits for swine rations are 15 percent (dry weight basis) for growing and reproducing rations and 20 percent for finishing rations.[7] This means that DDGS can replace about one-half of the soybean meal normally fed. For poultry rations the DDGS feeding limit is even more severe as only ten percent of the ration may be DDGS.[7] From a nutritional standpoint it is possible to have a beef or dairy ration composed almost totally of DDGS. However, it is not very economical as excess protein is fed. This excess protein then, has value as a source of feed energy only. Thus, for economic reasons DDGS should only replace the soybean meal fed. The quantity of DDGS produced per gallon of alcohol is approximately seven pounds.

Milling Process

Dry milling and wet milling are two methods for processing corn into food and feed products. The products produced by milling corn are starch, corn oil, corn gluten meal, and corn gluten feed. Starch makes an ideal alcohol fuel feedstock. Thus, a corn milling plant and an alcohol plant can be combined to produce alcohol fuel along with the other products of corn milling. Currently, most alcohol fuel plants being designed use the conventional distillery processing method. One firm that designs a combination corn milling-alcohol fuel plant is Chemapec, Inc.[2,3] Its engineering estimates were used in this analysis. The Chemapec process first dry mills the corn to obtain corn oil. A starch slurry is then formed. Enzymes are added to the starch slurry to form a syrup containing sugar, fiber and gluten. The syrup is centrifuged to separate the sugars from the fiber and gluten. The sugar is then sent to the fermentation tanks where alcohol is produced. The fiber and gluten are dried to produce corn gluten feed and corn gluten meal. The slop that remains after distillation contains few feed nutrients. Therefore, it is not considered for use as a feed, but instead it is used to produce methane gas. The methane gas generated reduces the quantity of purchased heat energy required by 50 percent to less than 20,000 BTU's per gallon of alcohol and is thus a potential source of cost reduction. The Chemapec process also recovers the yeast used in fermentation for use as a livestock feed (fodder yeast).

The quantities of by-products produced per gallon of alcohol by the Chemapec process are corn oil, .7 pounds; corn gluten meal, 1.6 pounds; corn gluten feed, 4.1 pounds; and fodder yeast, .4 pounds. Keim reports that wet milling process produces .7 pounds of corn oil, 1.3 pounds of corn gluten meal, and 4.5 pounds of corn gluten feed per gallon of alcohol fuel produced.[5]

The by-product feeds produced by dry milling are better substitutes for soybean meal than DDGS as they have more protein and less fiber. Corn gluten meal has 43 percent crude protein and five percent fiber. Corn gluten feed has 26 percent crude protein and seven percent fiber. The protein content of fodder yeast is 48 percent and the fiber content is three percent.[6] With more protein and less fiber than DDGS, the feeding of corn gluten meal and fodder yeast in swine rations can be increased by up to 50 percent. The feeding of corn gluten meal can also be increased in poultry rations. Research done by Poos and Klopfenstein demonstrated that corn gluten meal is 46 percent more efficient as a protein source than DDGS.[9] The feeding limitations for corn gluten feed are very similar to that of DDGS. Thus, to make the best use of milling feed by-products, corn gluten feed should be fed to beef and dairy livestock while corn gluten meal and fodder yeast should be fed to swine and poultry livestock.

MICRO OR FIRM LEVEL ECONOMIC ANALYSIS

In comparing the per gallon processing cost for both methods one finds: the milling method has a non-energy operating cost advantage of five cents, an energy cost advantage of two cents, a capital cost disadvantage of ten cents, and a by-product credit advantage of 17 cents for a total advantage of 14 cents over the distillery method (Table 1). Even though the milling method has a lower processing cost than the distillery method, the distillery method may be favored by some alcohol fuel producers as it has a lower capital or start-up cost.

Total alcohol fuel cost is $1.17 per gallon for the milling method and $1.31 per gallon for the distillery process. With these costs alcohol fuel is still more expensive than gasoline at the current wholesale price of $1.04 per gallon.[1] Alcohol fuel production is economically feasible though when the 40 cents per gallon federal subsidy is added. (The subsidy is from the elimination of the federal excise tax.)

In summary, the individual producer can receive higher long run returns from processing corn into alcohol fuel if he uses the milling method even though the distillery method has lower capital ad start-up costs.

MACRO OR INDUSTRY LEVEL ECONOMIC ANALYSIS

Producing large quantities of alcohol fuel will increase corn prices and thus food prices. The choice of alcohol fuel processing method may have a cumulative impact on the level of food price increases. This in turn would point toward a needed policy to influence private investment decisions on fuel processing methods. An alcohol-agricultural model has been built to compare the food price increases resulting from alcohol fuel being produced by both the distillery and milling processes.

Table 1: Comparing Alcohol Fuel Production Costs: Conventional Distillery vs. Milling

Costs[1,2]	Alcohol Fuel Processing Method	
	Conventional Distillery	Milling[3]
	(Dollars per Gallon)	
Non-Energy Operating	.31	.26
Energy	.07	.05
Total Operating	.38	.31
Capital[4]	.33	.43
Total Processing	.71	.74
Corn[5]	1.13	1.13
Total Cost	1.84	1.87
By-Product Credit[6]	- .53	- .70
Net Alcohol Cost	1.31	1.17

1. Based on 20 million gallons annual production
2. 1979 costs updated
3. Chemapec Process
4. Amortized over 20 years at 13 percent interest
5. $2.83/bushel (average price received by farmers, Jan.80 to April 81)
6. From Table 2.

Table 2: Quantity and Value of Alcohol By-Products Produced From Corn under Conventional Distillery and Milling Processing Methods

Process/By-Product	Pounds	Prices[1]	Value
	(per 1000 gals.)	($/ton)	(¢/gallon)
Distillery			
DDGS	7120	148	52.7
Milling[2]			
corn gluten meal	1580	259	20.5
corn gluten feed	4080	125	25.5
fodder yeast[3]	440	202	4.4
corn oil	730	522	19.1
Total	6830		69.5

1. Average prices from Jan. 1980 to April 1981

2. Chemapec Process

3. Fodder yeast prices are not reported in the Feed Outlook and Situation; soybean meal prices were used instead.

Sources: Chemapec, Inc. (2,3)
U.S. Department of Agriculture (10,11)

An Alcohol-Agricultural Model

The alcohol-agricultural model represents Western Ohio Corn Belt agriculture with 1977-1979 as the base time period. The model has crop, livestock, transportation, and alcohol fuel processing activities. The crop activities are corn grain, corn silage, soybeans, wheat, oats, and hay. Beef fattening, milk (dairy), lamb, chicken, turkey, and eggs (layers) are the livestock activities. There are two swine feeding activities. One activity limits the feeding of by-product feeds to that feed performance and rate of gain are not affected. The second swine feeding activity allows twice as much by-products to be fed. The expense or trade-off of increased by-product feeding is reduced feed performance which in turn raises production costs. Thus, the second swine feeding activity will be used only when the benefits of feeding extra by-products are greater than the extra costs.

The model determines both quantity and price for the various commodities. In developing the model it was assumed that other parts of the country would also be producing alcohol fuel. Thus, the model cannot "import" corn from other areas. Also, by assuming that other regions are producing alcohol fuel, the model can generate national price responses to changes in commodity production.

The model then is forced to produce alcohol fuel at four different levels: 100, 200, 300, and 400 million gallons. These alcohol fuel levels correspond to national levels of 2.6, 5.2, 7.7, and 10.3 billion gallons respectfully. During 1980, 100 billion gallons of gasoline were consumed in the United States.[12] This level of gasoline consumption would require 10 billion gallons of alcohol fuel if gasohol were to replace gasoline. Thus, the model's 400 million gallon level represents the quantity of alcohol fuel needed for a national gasohol program.

Comparison of Food Price Increases

The food price increases are calculated using the Laspeyres Index. The Laspeyres Index measures the cost, relative to the base period, of purchasing the base-year quantities at the given year prices.[4] For our purpose the base period is when no alcohol fuel is produced and the given year prices are the equilibrium prices of the different alcohol fuel levels. The food commodities are beef, pork, lamb, chicken, turkey, eggs, milk, soybean oil, wheat, corn, and oats. For soybean and oil, wheat, corn, and oats only the quantities consumed domestically for food are included in the food price calculations (livestock feed and export uses are excluded).

Results from the model show that at low alcohol fuel production levels there is very little difference in food price increases between the two processes, but at high alcohol fuel production levels the increase in food prices is substantially greater for the conventional distillery process (Table 3). The difference in food price increases starts to become significant at 300 million gallons as the food price increase is 3.8 percent for the milling process and 4.7 percent for the distillery process. At 400 million gallons the increase in food prices for the distillery is 12.1 percent, which is almost double the 6.9 percent increase for the milling process. Thus, the milling process can substantially minimize the impact of a national gasohol program on food prices.

Explanation of Results

The lower food price increases for the milling process can be explained by the more efficient use of alcohol fuel by-products (Tables 4 and 5). When the distillery process is used, 356,000 tons of DDGS are produced per 100 million gallons of alcohol fuel. For the milling process 305,000 tons of by-product feeds plus corn oil are produced per 100 million gallons of alcohol fuel. However, the quantity of soybean meal replaced by feed by-products is greater for the milling process. This is because its feed by-products are better substitutes for soybean meal than DDGS. At first there is little difference in the quantity of soybean meal replaced by each process. But by 300 million gallons, the quantity of soybean meal being replaced by the milling feed by-products is significantly greater than the quantity being replaced by DDGS. As alcohol fuel production increases to 400 million gallons the difference increases. This is because swine can consume more feed by-products when the corn is milled. At 400 million gallons swine consumed 225,000 tons of milled by-product feeds compared to 131,000 tons of DDGS. This additional by-product feeding greatly reduces the quantity of soybean meal fed--from 185,000 tons for the distillery process to 42,000 tons for the milling process. Thus, the milling process results in more soybean meal being sustituted as it provides high protein feeds that can be better utilized by livestock.

The importance of more complete substitution of by-products for soybean meal is that more soybean land can be released to corn production, to meet the additional corn demand caused by alcohol fuel production. This in turn, lessens the effects on other crop and livestock production, thus minimizing price changes. When by-product feeds can no longer substitute for soybean meal, then soybean acreage can not be reduced as more alcohol fuel is produced. Now the additional land for increased corn production comes from other crops. This reduces their production and increases their prices. Also, some of the corn for alcohol fuel then comes from reduced livestock feeding and this results in higher livestock prices, and therefore higher food prices.

The changes in crop production for both processes are shown in Table 6. At first the changes are similar as the decline in soybean

Table 3: Food Price Increases Caused by Alcohol Fuel Production

Alcohol Fuel Production Level	Distillery Process	Milling Process
(million gallons)	(percent increase)	
100	0.1	0.1
200	2.0	1.9
300	4.7	3.8
400	12.1	6.9

Table 4: High Protein Feeds: Usage and Price
Conventional Distillery Process

Item	0	100	200	300	400
	Alcohol Fuel Production Levels (million gallons)				
	(quantity - 1000 tons)				
Soybean Meal					
Ruminants	149	-	-	-	-
Pork	244	185	185	185	185
Poultry	130	129	128	83	81
Marketed	1034	993	805	706	681
Total	1557	1307	1118	974	947
DDGS					
Ruminants	-	141	140	146	280
Pork	-	131	131	131	131
Poultry	-	-	-	86	84
Marketed	-	84	441	705	929
Total	-	356	712	1068	1424
	(price - $/ton)				
Soybean Meal	187	187	194	183	198
DDGS	-	144	149	122	119

Table 5: High Protein Feeds: Usage and Price
Dry Milling Process Model

Item	Alcohol Fuel Production Levels (million gallons) 0	100	200	300	400
	(quantity - 1000 tons)				
Soybean Meal					
Ruminants	149	-	-	-	-
Pork	244	182	146	131	42
Poultry	130	74	74	73	72
Marketed	1034	1029	856	662	650
Total	1557	1285	1076	866	764
By-Product Feeds					
Ruminants	-	150	149	148	284
Pork	-	91	157	160	225
Poultry	-	64	63	63	62
Marketed	-	-	241	544	649
Total	-	305	610	915	1220
	(price - $/ton)				
Soybean Meal	187	189	198	207	200
Corn Gulten Meal	-	186	194	203	160
Corn Gluten Feed	-	139	143	149	113
Fodder Yeast	-	193	201	210	162

Table 6: Comparing Changes in Crop Acreage Due to Alcohol Fuel Production--Conventional Distillery Process vs. Dry Milling Process

Process/Crop	Alcohol Fuel Production Levels (million gallons) 100	200	300	400
Conventional Distillery		(1,000 acres)		
Corn	+321	+605	+882	+1,073
Soybeans	-310	-562	-782	- 857
Wheat	- 8	- 27	- 63	- 124
Oats	- 2	- 10	- 23	- 54
Corn Silage	---	- 1	- 2	- 6
Hay	- 2	- 6	- 12	- 35
Dry Milling				
Corn	+349	+658	+969	+1,249
Soybeans	-337	-614	-891	-1,078
Wheat	- 8	- 27	- 46	- 106
Oats	- 2	- 11	- 19	- 36
Corn Silage	---	- 1	- 2	- 4
Hay	- 2	- 6	- 10	- 24

Note: Total changes may not sum to zero due to rounding error.

meal usuage is similar. At 300 million gallons and beyond the decline in soybean acreage becomes significantly greater for the milling process as it substitutes more soybean meal than the distillery process. Thus, the acreage of corn and other crops are greater for the milling process and this results in less of a food price increase.

In conclusion there are clear potential advantages for the milling process. For the individual alcohol fuel producer the milling process offers increased earnings though capital costs and hence start up costs are greater. For society the milling process results in more efficient utilization of the by-product and thus much lower food price increases when alcohol fuel is produced.

SUGGESTIONS FOR FUTURE RESEARCH

The economics of alcohol fuel production, for both the individual producer and society, is dependent on the efficient use of the residues. A key area of research, therefore, is to improve the efficiency of use of these residues or by-products. The principal by-product use is for livestock feed. Yet little information is available on a broad range of livestock performance rates. To improve feed by-product use we need to know more precisely the maximum quantity that can be fed to each type of livestock without adversely affecting their performance. Futher we need to know how livestock performance will be affected when by-products are fed in excess of this maximum quantity. This is needed to determine the most economical by-product feeding rates under various levels of by-product supplies. In searching for more efficient use of byproducts, researchers should not limit themselves to just livestock feeding. Using by-products as human food should also be investigated.

A second research area deals with alcohol fuel plants. Currently, there are few alcohol fuel plants using the milling process. Because public performance data for the milling process is limited, this study used estimated engineering data. Public performance data on the various milling processes is needed to more critically evaluate alternative processes. This will help potential alcohol fuel producers make a more informed decision on which type of process is right for them.

Finally, continued research needs to be done on the macro economic consequences of producing different types of by-products. This study is an initial attempt in this area. A limitation of this study is its regional approach. The entire country as one unit, as well as regions outside of the Corn Belt with different alcohol feedstocks and by-products, should be analyzed in order to gain additional information on the influence that by-products have on the economics of alcohol fuel production.

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